THEORETICAL ANALYSIS ON THE WIND POWER AND PUMPED HYDROPOWER STORAGE INTEGRATED FLOOD MITIGATION SYSTEM

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SUPERVISOR’S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Science

Faculty of Mechanical Engineering

UNIVERSITI MALAYSIA PAHANG

MARCH 2019

ACKNOWLEDGEMENTS

Firstly, all the praise and gratitude to Allah S.W.T for giving good health and strength to me to complete my project successfully. Many people helped me throughout my project journey, there are no words to describe their contribution and time spent to help me to complete my project. Sincerely, I would like to thank each one of them and apologise for any of my mistake or behaviour.

I am grateful and like to express my sincere gratitude to my supervisors Prof. Dr. Hj. Shahrani bin Hj. Anuar and Dr. Mohamad Firdaus bin Basrawi for their germinal ideas, invaluable guidance, continuous encouragement and constant support who have been my biggest inspiration throughout this project till my research study was completed successfully. They were always willing to help me whenever I face a problem with my research. Also, they were constantly guiding me with their immense knowledge and experience, from the beginning till to the end, and also in the course of writing this thesis.

Additionally, I would like to thank my co-supervisor, Dr. Daing Nafiz and also Dr. Ahmmad Shukrie for their guidance, suggestion, comment and co-operation in this project. Besides that, I sincerely would like to thank staff of Mechanical Engineering Department, UMP, who were always available to assist me throughout my research work.

Above all, I acknowledge my sincere indebtedness and gratitude to my parents and my family members for their love and sacrifice throughout my life by supporting me morally and financially. I also wish to acknowledge my appreciation and convey sincere thanks to my fellow friends who encouraged me motivationally and provided moral support for me throughout the project until its successful completion.

ABSTRAK

Kesan serta-merta banjir menyebabkan kehilangan nyawa manusia dan kerosakan kepada harta benda. Langkah semasa untuk pencegahan banjir adalah lebih kepada keperluan segera untuk menyediakan bantuan segera ketika banjir. Oleh itu, mengintegrasikan takungan banjir dengan hidroeletrik simpanan-pam seolah-olah penyelesaian yang meyakinkan untuk masalah banjir. Hidroeletrik simpanan-pam pada dasarnya dikenali sebagai satu alat penyimpanan yang boleh meningkatkan kebolehpercayaan sumber tenaga tidak tetap. Namun, terdapat isu dengan kos kuasa angin hidroeletrik simpanan-pam (KAHSP) yang mana adalah mahal untuk dibina. Oleh itu, KAHSP memerlukan nilai tambah supaya pembinaan kemudahan simpanan tenaga ini berbaloi untuk dibina. Takungan KAHSP boleh menyimpan air dalam jumlah yang banyak dan jika dibina dengan mekanisma yang sama dengan takungan banjir, ianya berkemungkinan mampu untuk mengatasi banjir ketika keadaan hidrologi yang ekstrem dan memberikan pelbagai faedah, terutamanya dari segi ekonomi. Oleh kerana keupayaan takungan KAHSP dalam mengatasi banjir dan kos yang tinggi bagi projek tersebut, adalah berguna untuk mengkaji impaknya dari segi ekonomi dan alam sekitar. Oleh itu, kajian ini bertujuan untuk menilai prestasi kuasa angin hidroeletrik simpanan-pam berintegrasi sistem penebatan banjir dari segi ekonomi dan alam sekitar. Perisian Optimization Hybrid Model Electric Diperbaharui (HOMER) digunakan untuk mensimulasi dan membandingkan sistem penjanaan kuasa yang mempunyai takungan banjir dan juga tanpa takungan banjir. Kemudian, aspek ekonomi untuk setiap sistem ditentukan berdasarkan kos bersih projek dan juga kos seunit tenaga. Manakala, impak alam sekitar dinilai berdasarkan jumlah pelepasan bahan pencemar ke udara. Didapati bahawa jumlah takungan air untuk mengatasi banjir adalah sebanyak 8,396,256 m^3 dan loji kuasa yang dicadangkan dianggarkan mampu menampung 69% daripada keperluan tenaga di salah satu daripada kawasan banjir dengan nilai kuasa pengeluaran sebanyak 0.7 MW dan kuasa input sebanyak 1.2 MW. Berdasarkan simulasi oleh HOMER, sistem grid (B-I) yang mana tanpa takungan air banjir adalah sistem yang terbaik dengan kos bersih projek hanya RM 0.38 juta dan kos bagi seunit tenaga adalah sebanyak RM 0.246/kWh. Namun, apabila kos kerugian banjir disertakan dalam kos bersih projek, sistem diesel/turbin angin/ takungan air (A-III) dan sistem grid/turbin angin/ takungan air (B-III) mempunyai kos bersih lebih murah berbanding sistem lain yang tidak mempunyai takungan untuk mengatasi banjir. Kos bersih bagi sistem A-III adalah RM 1.52 juta dan bagi sistem B-III adalah RM 1.37 juta, manakala bagi sistem B-I adalah sebanyak RM 10.4 juta apabila kos kerugian banjir disertakan sekali dalam jumlah keseluruhan kos bersih projek. Antara sistem yang menyertakan sekali takungan dalam rekabentuknya, jumlah pelepasan bahan pencemar daripada sistem A-III adalah sebanyak 408 kg gas karbon diosida dalam setahun yang mana lebih rendah daripada sistem B-III iaitu sebanyak 29,662 kg gas karbon dioksida dilepaskan dalam jangka waktu yang sama. Oleh yang demikian, boleh dikatakan A-III adalah sistem penjanaan kuasa yang terbaik kerana menawarkan manfaat dari segi aspek ekonomi dan alam sekitar.Tetapi, saiz takungan A-III yang dicadangkan hanya boleh mengumpul 20.8 % daripada keseluruhan lebihan air yang dijana dari keseluruhan basin Pahang. Adalah hampir mustahil untuk hanya satu takungan air untuk mengumpul lebihan air yang dijana dari basin yang besar. Oleh demikian, beberapa takungan air boleh dibina untuk mengumpul lebihan air sebagai langkah pencegahan banjir. Kesimpulannya, sistem penebatan banjir bersepadu tenaga angin hidroeletrik simpanan-pam kelihatannya memberi manfaat dalam aspek ekonomi dan persekitaran.

ABSTRACT

The immediate consequences of flood causes loss of human life and damage to property. The current flood mitigation was more on the urgent need to provide immediate flood relief works. Thus, integrating flood reservoir with pumped hydropower storage seems a promising solutions for flood problems. Pumped hydropower storage is basically known as a storage device that can improve the reliability of the intermittent source of wind energy. But, there is an issue with the cost of a wind power pumped hydropower storage (WPHS) as it can be expensive to construct. Thus, WPHS requires an additional value so that it is worth to construct this storage facility. The reservoir of WPHS can store huge amount of water and if it is designed with similar mechanism of flood reservoir, it may be capable to mitigate flood during extreme hydrological events and render significant benefits, especially in the terms of economic aspects. Due to the feasibility of WPHS reservoir in flood mitigation and the high cost of the projects, it is beneficial to study economic and environmental aspects of WPHS. Thus, this research aims to evaluate economic and environmental performances of wind-power pumped hydropower storage integrated flood mitigation system. The Hybrid Optimization Model for Electric Renewable (HOMER) software was used to simulate and compare power generation system with and without the flood reservoir. Then, the economic aspects of each system were evaluated based on the Net Present Cost (NPC) and Levelized Cost of Energy (LCOE). Meanwhile, environmental impacts were evaluated based on the amount of air pollutants released to the environment. It was found that the estimated volume of the reservoir to attenuate flood event was 8,396,256 m^3 and the proposed power system was estimated to support 69% of energy demand in one of the flood-prone areas with a mean value of power output being 0.7 MW and power input 1.2 MW. Based on the simulation in HOMER, the grid standalone system (B-I) which is without flood reservoir is the optimum system with the NPC only RM 0.38 million and the LCOE RM 0.246/kWh. But, when the cost of flood losses are internalised in the total NPC, the wind-diesel with reservoir storage system (A-III) and the wind-grid with the pumped hydro storage system (B-III) will have much lower NPC than other systems that do not include reservoir for flood mitigation. The NPC for system A-III is RM 1.52 million and for system B-I is RM 1.37 million; meanwhile, the NPC for system B-I is RM 10.4 million when the cost of flood losses are included in the total NPC. Between both energy systems which included the reservoir in their design, the amount of pollutants emitted by the A-III system is 408 kg of carbon dioxide per year which is much less than the B-III system which is 29,662 kg of carbon dioxide during similar period. Therefore, it can be said that the A-III system is the most optimum power generation system as it offers benefits in both economic and environmental aspects. But, the suggested size of reservoir for A-III only can capture 20.8 % of excess runoff generated from the whole Pahang basin. It is almost impossible to expect only a reservoir to capture all excess runoff generated from a large basin. A few reservoir can be built at each sub basin to capture the excess runoff as a flood prevention. In conclusion, the WPHS integrated with flood mitigation system seems beneficial in the term of economic and environment.

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LIST OF SYMBOLS

$C_{ann,tot}$	Total annualized cost, USD/year
C_B	Capacity, A. h
CO	Carbon monoxide
CO_2	Carbon dioxide
e_g	Generator efficiency
E_{M-P}	Charging power, W
$E_{G\text{-}T}$	Energy generated from the turbine-generator, kWh
E_R	Storage capacity of the reservoir, kWh
E_S	Energy stored, kWh
f	Friction factor
g	Acceleration due to gravity, m/s^2
h	Head height, m
h_f	Head loss due to friction, m
i	Interest rate, %
I_a	Initial abstraction, mm
l	Length, m
L	Lag, hr
L_g	Length of grid, m
L_W	Length of penstock for water, m
n	Friction factor manning's
NO_x	Nitrogen oxides
P	Rainfall, mm
P_{bat}	Power produced by the battery, W
P_C	Power capacity, W
Q	Volumetric flow rate, m^3/s
Q_a	Peak post-development, m^3/s
Q_i	Peak inflow, m^3/s
Q_O	Peak outflow, m^3/s
Q_p	Peak pre-development flow, m^3/s
r	Radius, m
R	Runoff, mm
S	Potential maximum retention after runoff/ slope, mm
SO_2	Sulphur dioxide
T_i	Duration of basin inflow, sec

t_c	Time of concentration, hr
V	Velocity, m/s
V_S	Volume of reservoir, m^3
ρ	Density of water, kg/m^3
η	Efficiency
η_P	Pump efficiency

LIST OF ABBREVIATIONS

CN	Curve Number
COE	Cost of Energy
DID	Drainage and Irrigation Department
EPRI	Electric Power Research Institute
HEC-HMS	Hydrology Modelling System
HOMER	Hybrid Optimisation Model for Electric Renewable
ICOLD	International Commission on Large Dams
MSMA	Manual Saliran Mesra Alam
NRSC	National Resources Conservation Service
NHA	National Hydropower Association
NPC	Net Present Cost
O&M	Operating and Maintaining
PHS	Pumped Hydropower Storage
PDTP	Pejabat Daerah dan Tanah Pekan
PSD	Permissible Site Discharge
RME	Relative Mean Error
RMSE	Root of Mean Square Error
SCS	Soil Conservation Service
TNB	Tenaga Nasional Berhad
VBA	Visual Basic for Applications

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